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September 1980

REPORT TO CONGRESS

on

FIREFIGHTER SAFETY

and

HEALTH

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FEDERAL EMERGENCY MANAGEMENT AGENCY
Washington, D. C. 20472

TO THE READER

The Federal Emergency Management Agency (FEMA) was established to reduce the economic and social devastation caused by natural and human-made disasters, through hazard mitigation and emergency management.

FEMA recognizes the important role our Nation's firefighters play in this effort. No matter what the disaster, the first team on the scene is usually the fire service and they diligently work to reduce the loss of lives and property under extremely hazardous conditions.

It is no wonder then that firefighting is high on the list of dangerous occupations.

If we are to reduce the loss of lives and property resulting from disasters, we must protect and assist this valuable resource, trained for the management of emergencies in this Nation. I have directed the U.S. Fire Administration to continue to exercise a leadership role in firefighter safety and health issues.

John W. Macy, Jr.
Director

FEDERAL EMERGENCY MANAGEMENT AGENCY
United States Fire Administration
Washington, D. C. 20472

Firefighters continue to have exceptionally high death and injury rates. The U.S. Fire Administration is dedicated towards making the firefighter's job safer.

Over the past few decades, the occupational safety and health of the industrial worker has received increasing attention from the Federal Government. This attention has influenced many changes, and as a result industrial workers now have fewer occupationally related deaths and injuries.

Safety and health matters of our Nation's firefighters, on the other hand, have been sadly neglected at the Federal level and deserve their fair share of attention. We feel that a concerted effort such as recommended in this report would greatly reduce the problem, saving anguish and injury to the firefighter and reducing costs in the long run to the taxpayer.

The importance of this report cannot be overemphasized. If we are to expect firefighters to risk their lives to save us, we must make a commitment to provide them with the best possible protective equipment and training available.

Gordon Vickery
Administrator

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FIREFIGHTER SAFETY AND HEALTH:

THE U.S. FIRE ADMINISTRATION'S

REPORT TO CONGRESS

PREFACE

Each year 100,000 firefighters are injured in the United States, many seriously. Lung injuries, burns, sprains, strains, wounds, and cuts are commonplace in virtually every fire department, large or small. An average of 650 full-time firefighters retire each year because of occupational illnesses such as heart disease, emphysema, and respiratory edema. And each year between 160 and 175 firefighters die in the line of duty.

Firefighting continues to be one of the Nation's most hazardous occupations. Recent published statistics of the U.S. Department of Health, Education and Welfare "show that the death rate of all cardiovascular diseases. . . is higher in firefighters than in police officers, longshoremen, construction workers, smelters, and furnacemen."[1] Further, while we estimate that about 100,000 firefighters were injured in 1978, the Mine Safety and Health Administration indicates that only about 35,000 miners were injured. Not only is the number of firefighter injuries greater than that of miners, but the firefighter injury rate also is greater. The firefighter injury rate is twice that of miners, even when volunteer firefighters, whose work exposure time is generally not equal to that of paid full-time firefighters, are included. If an equivalent exposure time for volunteers were known, the firefighter injury rate would be even greater than that of miners.

None of these estimates can be made with certainty -- that, in fact, is one of the problems. But there is no doubt that large numbers of firefighters die and are injured each year.

In a Proclamation issued in August 1979 to mark Firefighters' Memorial Sunday, President Carter said: "We must do more to reverse the trend toward more injuries and deaths of firefighters."

The U.S. Fire Administration, since it began in 1974 has had to concentrate on America's overall fire problems, among the world's worst. Difficult decisions have had to be made about when to take money away from citizen protection programs to begin work to improve protection for our country's firefighters. Most often the citizen has come first, a reflection of what happens in our towns and cities every day.

But the increasing imbalance of this approach, and the new dangers to the firefighter -- toxic-gas-producing synthetic materials in homes; hazardous materials spills and explosions; fire in high-rise buildings; plus the increased costs for medical care, workman's compensation, and retirements -- have now spurred serious concern for the need for all sectors, Federal, state, and local government, our Nation's fire departments, both paid and volunteer, the research community, and private industry, to aggressively work together to turn the corner on the course of the firefighter safety and health problem in the United States.

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FIREFIGHTER SAFETY AND HEALTH:

THE U.S. FIRE ADMINISTRATION'S

REPORT TO CONGRESS

The Congress, recognizing the need for further action to improve firefighter safety and health programs, mandated the U.S. Fire Administration in November 1979 to "conduct a review of firefighter safety" and to "submit to Congress the results of such review."[2]

This report presents the U.S. Fire Administration's response to that mandate. It examines the safety and health problems of America's firefighters, describes current efforts to solve those problems, points out specific needs which are not being addressed, and describes for the United States Congress what is needed to solve this tragic problem.

THE NATURE OF THE FIREFIGHTING JOB

By its very nature, firefighting is a high stress occupation. Firefighters are repeatedly subjected to rapid, unanticipated transitions from the friendly environment of the fire station to the hostile environment of a fire. Not only are the transitions extreme emotionally -- from calm to crisis, from safety to danger -- but they are also physically extreme -- from shirt-sleeves to an inferno.

Research has shown that within 15-30 seconds after the sound of an alarm a firefighter's heart rate can increase by as much as 117 beats per minute and that it can continue to beat at more than double the normal rate during actual firefighting operations.[3] Documented case histories have shown that stresses like those have precipitated severe coronary problems.

The fact that the firefighter must work in extreme temperatures -- high and low -- compounds the problems caused by stress. At times, a firefighter and his equipment can be exposed to sub-freezing temperatures on the way to the fire and then to temperatures commonly between 100°F and 500°F at the fire itself. On some occasions that firefighter also can be exposed to backdrafts with temperatures up to 1,500°F, for at least a few seconds.

The firefighter's exposure to such temperature extremes results in physiological risks ranging from minor injury to death. Effects include frostbite; a wide variety of cardiovascular and pulmonary disorders such as acute circulatory collapse, hypertension, pneumonia, and bronchitis; fainting from heat; exhaustion; and burns.

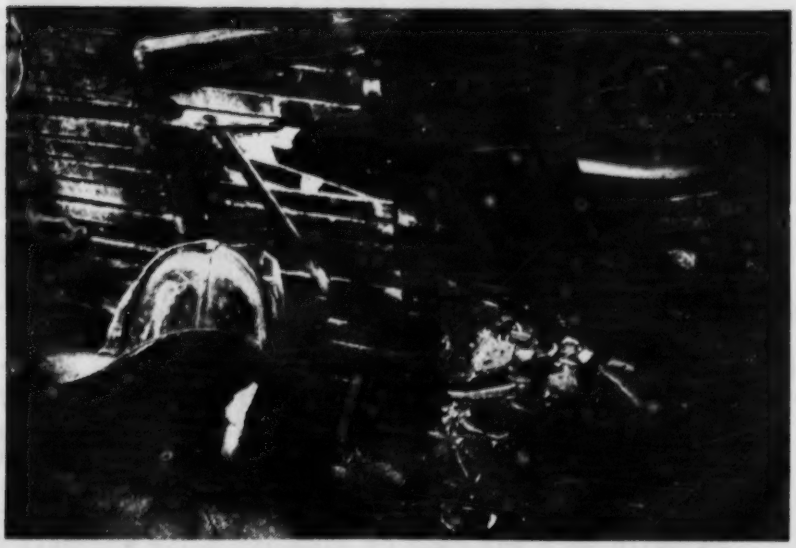
The strenuousness of the firefighter's work on the fireground produces additional physiological strain. Fireground operations occur in three phases: rescue, extinguishment, and overhaul. During rescue and extinguishment firefighters work as a highly coordinated team. The work includes such strenuous physical actions as manually raising ladders to two and three stories, climbing onto roofs with heavy axes and cutting holes in them to ventilate the burning structure, rapidly conducting search and rescue activities, making difficult hose hook-ups, pulling and carrying -- often up stairs -- heavy hoses to the fire, and fighting water pressure to keep the hose directed at the flames. The firefighter performs all of these tasks in boots, helmet, and turnout coat, usually over his station clothes, which means he is carrying 20-30 lbs. of extra weight at a minimum.

Smoke, the main killer in fires, complicates a firefighter's work and adds further to the stress and danger. Wearing breathing apparatus means carrying another 30-35 lbs. of dead weight, additional awkwardness, and worry about running out of air. Of course, without a mask, smoke is irritating to the eyes, nose, throat, and upper respiratory system. Its opacity hinders search and rescue activities.[4] Smoke is composed of many toxic gases such as carbon monoxide, acrolein, hydrogen cyanide, and benzene which contribute to further hazards for the firefighter. The degree of toxicity depends on the nature of the material burning,[5] the intensity of the heat, whether the fire is free burning or smoldering, and the time spent at the fire, but even short-term exposure can impair judgement and decision-making -- both crucial to the firefighter's survival.

The firefighter is exposed to explosions, blows to the head and other parts of the body, electric shock, lacerations by sharp objects, and the effects of hazardous liquids and gases. In addition to their immediate effects, these can result in additional problems such as strokes, infection, acoustic trauma, and other physical complications.

Firefighting tactics also impact on the firefighter's safety. For example, advocates of "interior firefighting" -- fighting a fire from within the burning structure -- assert that the seat of the fire can be reached more rapidly with this approach and that the economic loss and water damage to the structure are reduced dramatically. Advocates of "exterior firefighting" hold that fighting the fire from the outside does not cause significantly greater economic loss or water damage but does provide more safety for the firefighter. The choice of tactics is a matter of tradition and judgement; in the United States, fires are usually fought from the inside. While the resulting loss per fire is less in the United States than in most other western countries, the danger to the firefighter is also greater.

Even when the fire is "knocked down" and apparently "out" the firefighter has more work to do. During overhaul operations the firefighter must search through debris, pull down ceilings and walls, and move furniture to ensure that every burning ember is extinguished and the structure is safe for others to enter -- all physically demanding tasks.



Back at the fire station, before he can rest the firefighter must prepare his equipment and apparatus to be ready for the next alarm. Between alarms, he may also be required to participate in training drills, emergency first aid, and support operations.

It is obvious from the description above that a firefighter needs adequate training and protective equipment and a healthy body to survive in the job. But the fact is that today's equipment is not adequate, and training and physical conditioning are often inadequate as well.

MAJOR PROBLEMS IN FIREFIGHTER SAFETY

Inadequate Protective Clothing and Equipment

The firefighter's primary defense against death and injury is his personal protective outfit, which consists of his "turnout" clothing and ancillary equipment, such as breathing apparatus, portable lights, and radio. The main problem for firefighters is that the present style of "full-up" turnout gear which has been in use for years has proven to be inadequate in many aspects. In addition, today's turnout gear in cumbersome, hot, and heavy, and does not provide adequate safety. Much of the current gear burns or melts too easily.

HELMETS

Helmets used in the fire service today may be made of the traditional leather or of glass-reinforced plastic, polycarbonate, or aluminum. The variety available allows the fire department or individual firefighter a choice in style and comfort and different levels of protection. Until recently, however, there was little guidance available to determine the levels of protection one could expect from any given helmet. Consequently, many of the helmets currently in use will soften or melt from heat, do not provide full head protection against impact and penetration, have limited or no resistance to water absorption and electrical hazards, and have unrealistically low flammability properties.

FACE SHIELDS

The devices usually worn by firefighters for eye and face protection consists of either a face shield attached to the helmet, safety goggles, or the face piece of their breathing apparatus. These protective devices are expected to protect the firefighter's eyes and face from the adverse effects of heat, irritating smoke, sparks, other airborne particles, caustic liquids, debris, and other hazards. The devices currently in use are usually fabricated from ploycarbonate or acrylic resins. They have been designed primarily for use in industry, where potential hazards either are controllable with back-up systems, such as fume-hoods with safety shields, or are much less severe than the hazards commonly experienced on

the fireground. In addition, most fire departments in the United States do not enforce safety practices that require the use of eye protection devices.

TURNOUT SUITS

The majority of our Nation's firefighters wear turnout coats, and sometimes turnout trousers, whose protective quality is achieved by a combination of an outer shell, a vapor barrier, and an inner thermal liner. Prior to the introduction of flame-resistant fabrics, the outer shell was manufactured with cotton duck or canvas. Besides being heavy (about 10 lbs.), the cotton duck and canvas shells were easily ignited in ordinary firefighting situations. Many departments continue to use these materials. Although the flame-resistant fabrics now available commercially have decreased the hazards of flames, weight has not been reduced significantly, and they present other problems such as shrinkage, lack of abrasion resistance, stiffness, and higher cost.

The middle layer of the coats and trousers, the vapor barrier, is designed to be impervious to steam, moisture, and any liquids which penetrate the outer shell such as high pressure water used in fighting fires. The material commonly used in vapor barriers is neoprene. Although effective in preventing the passage of outside moisture and liquids through the turnout coats, this material also prevents the passage of body heat from the inside out. Consequently, turnout coats become virtual sweat boxes and can cause hyperventilation, increased body temperature and heart rate, exhaustion, and fainting.

Thermal liners, the third component of turnout coats, are fabricated from a variety of man-made and natural materials and are usually designed for the local climate rather than the thermal environment of a fire. That is, they are not very good at protecting the firefighter from the transfer of the fire's heat to his body.

In addition to the deficiencies described above, turnout trousers also are cumbersome and restrict the movements of the lower body. As a consequence, the use of turnout trousers is limited in U.S. fire departments. Hip-length boots are used as an alternative, and are usually worn over the station uniform.

BOOTS

The rubber boots manufactured for firefighters are designed primarily to provide protection from water, and to provide warmth. However, they are heavy (almost 9 lbs.), inflexible, and uncomfortable to wear for extended periods of time. In addition, because of their bulkiness and weight the boots can be unsafe while riding and driving apparatus, climbing ladders, and working on the fireground wherever there is poor footing. Furthermore, most current boots are not fabricated from materials that will stand the rigors of high temperature and flames and do not provide adequate protection from blows and penetration.

GLOVES

Hand and wrist protection has been a neglected area in firefighter protective clothing as well. The firefighter's hands are his most important tools. Many of his routine duties require manual dexterity to grip and manipulate hand tools and to discern shapes of various objects -- and to locate possible unconscious victims -- when there is poor visibility. In order to function on the fireground, his hands must be protected from flames, sharp and hot objects, and water. In most cases, however, firefighters wear an industrial work glove selected on the basis of low cost and availability. These gloves may meet some protection needs, but the high frequency of injuries to hands and wrists (18 percent of the total injuries sustained according to 1978 data from the National Fire Incident Reporting System) clearly demonstrates that other protection needs are not met.

BREATHING APPARATUS

Currently the major portion of the fire service uses an open-circuit, self-contained breathing apparatus that was designed for use in industry and for mine safety and rescue, not for use in a hostile fire environment. This apparatus typically weighs 30-35 lbs., is uncomfortable to wear, and restricts the firefighter's movement. In addition, although it is rated for a 30-minute service life, the air supply typically lasts only 10-20 minutes, depending on the firefighter's work rate, physical condition, and size.

To further complicate the problem, deficiencies in a particular breathing apparatus unit in the fire environment often are not discovered until it is actually used in the field. Within the past year serious malfunctions were observed in two types of breathing apparatus used during firefighting. In one instance, serious malfunctions in the regulator diaphragms of an unreasonably large number of one type of breathing apparatus were discovered during use in firefighting operations. In another case, failures in the high pressure hose assembly of another manufacturer's breathing apparatus were uncovered in the field. In both cases, even though the firefighters were using "approved" breathing apparatus, they did not provide the protection necessary for their safety.

As a result of a NASA Technology Utilization Office project conducted in the early 1970's, an improved breathing system was developed and field-tested. Improvements included a 30 percent reduction in weight, redesign of the harness to increase comfort, and better visibility through the face mask -- all important advances. One

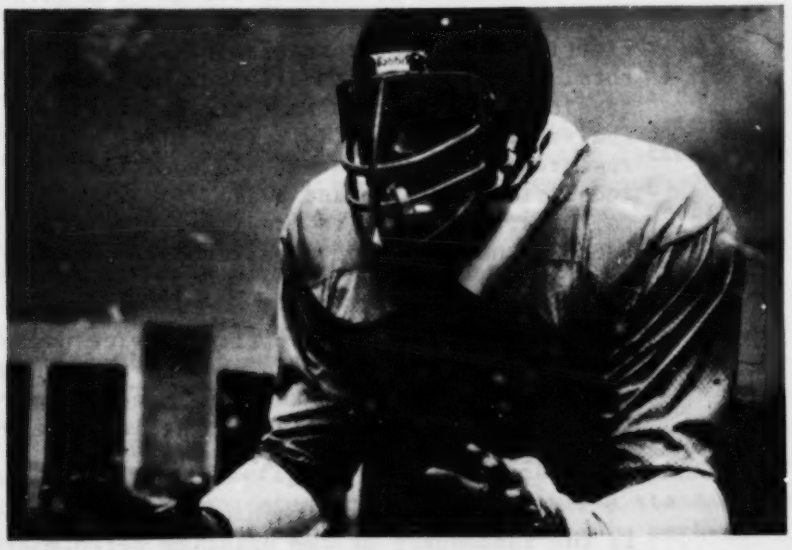
industrialized version of this improved system is currently available. But the new system is rated for the same 30-minute service life as current gear and still typically does not last that long during firefighting operations. Although it is more comfortable to wear, the size and shape of the apparatus still hampers movement in cramped spaces and restricts movement necessary to conduct some firefighting tasks. In addition, although the new breathing apparatus costs only slightly more than those in use now, it requires installation of a totally new high-pressure system for efficiently filling the tanks, which is expensive. Few departments have been willing to pay the cost of conversion to the new system.

TOOLS

Although breathing apparatus is relatively new and changing, the firefighter uses some tools which have not been changed in design or materials for generations. While it is true that the fireground environment dictates that rugged tools are required, these tools -- such as axes, crowbars, ladders, hoses, and hose couplings -- are made from materials that are often unnecessarily heavy and bulky.

The unwieldiness of many firefighting tools, plus the fact that the "man-machine interactions" (also called "human factors" or "human engineering") rarely are considered in the design of firefighting equipment, contribute to the high frequency of back injuries, strains, sprains, and physical exhaustion.

These deficiencies have existed for years in fire service equipment, despite technological innovations in protective clothing and equipment in other fields. While changes in firefighting gear have been slow, significant improvements have been made in outfitting race cars drivers with flame-resistant clothing, football players with improved helmets, and scuba divers with better breathing apparatus.



Marketplace Barriers

Since the basic technology already exists, why has the marketplace failed to provide better protective clothing and equipment for firefighters? Part of the fault may lie with the fire service itself, and part with the supplying industry.

FIRE SERVICE

The fire service typically is a conservative, tradition-oriented market which has limited resources -- now even more limited in light of the impact of

inflation and Proposition 13-type legislation -- for the purchase of protective clothing and equipment, and limited time and expertise to evaluate new equipment.

Since changes in specifications for protective clothing and equipment cost time and money -- and often the expenditure of much leadership energy in overcoming resistance to change -- it is easier and seems less expensive on the surface for departments to stick with "traditional" clothing and equipment. As a result, the introduction and acceptance of technologically advanced protective clothing and equipment is severely limited.

INDUSTRY

The fire service is served by a variety of industries ranging from large, diversified firms to small manufacturers of individual pieces of equipment such as helmets or turnout coats. The large firms, in some cases, consider the manufacture of fire-fighting equipment a supplemental part of their total business, and tend to invest research and development resources in their major product lines. The small firms usually have limited resources for research and development. In addition, the industries -- large and small -- have been reluctant to invest resources to adapt existing technology because the chance of acceptance by the fire service is limited.

These two factors -- fire service conservatism and industry fragmentation -- tend to reinforce each other and help explain the slow pace of improvements in protection for firefighters against death and injury in the line of duty.

Another factor which has stifled improvements is the inadequacy of the existing performance standards that specifically address firefighter protective clothing and equipment.

STANDARDS

The impetus for developing performance standards is to meet established safety and health regulations. The Occupational Safety and Health Administration (OSHA) was established to issue and enforce such regulations. The Federal Act that established OSHA mandated that standards be promulgated to address the safety and health of firefighters employed by the Federal Government, industrial companies, and private contract service companies.

However, municipal and volunteer firefighters, by far the vast majority of the firefighting population, are exempt from the Federal OSHA standards under the Occupational Safety and Health Act of 1970. This Act did provide for the development and implementation of Federally approved state OSHA plans which can supersede the Federal plan to cover the state's employees. Approximately half of the states have approved safety and health plans for their public employees, but only a few of these have addressed firefighter safety and health. Except for aggressive actions in some states, such as Washington and California, the state OSHA plans do not include meaningful performance standards for firefighter protective equipment.

Consequently, the development of performance standards for firefighter protective clothing and equipment has been left to voluntary standards organizations.

In the past, two associations have been actively involved in the development of consensus standards for protective clothing and equipment: the American National Standards Institute (ANSI) and the National Fire Protection Association (NFPA). Even though some efforts by ANSI have addressed the needs of firefighters, these have been limited and only include minor variations in existing standards for industrial workers. NFPA has been one of the most effective organizations in the promulgation of standards specifically addressing firefighter protective clothing and equipment.

To date, NFPA has published a voluntary standard for structural firefighters' turnout clothing, another for breathing apparatus, and most recently a standard for structural firefighters' helmets based in part on research conducted by the U.S. Fire Administration. Efforts by NFPA and others to develop additional standards have been hampered by the lack of data sufficient to determine the level of protection required.

In addition to these activities, the International Association of Fire Fighters published a set of Proposed Sample Standards for Firefighters Protective Clothing and Equipment. These standards, which were compiled to assist states in developing their state OSHA plans, were based on the standards

and specifications available at the time that had relevance to the functional and safety requirements of firefighters.

One point that must be made about the standards issued by these private organizations is that they do not become mandatory until some governing body at the local level references their use by law.

PERFORMANCE CERTIFICATION

While industrial workers' clothing and equipment are certified at the Federal level, no similar procedures have been established to certify that firefighters' clothing and equipment actually meet even the applicable voluntary standards. For instance, in 1976 the National Institute for Occupational Safety and Health (NIOSH) found that three out of six helmets advertised as meeting requirements of ANSI Z89.1 -- at that time the accepted standard by OSHA for firefighter helmets -- fell short of passing the performance tests for that standard. Therefore, the purchasers of equipment must either take it on faith that the equipment has been manufactured to the standard or conduct independent tests to ensure the performance criteria are met.

Most fire departments and local and state occupational safety and health groups do not have the resources or expertise to validate that the standards have been met. As a result, a fire department can, and often does, purchase protective clothing and equipment that does not meet the minimum standards and may, in fact, itself contribute to firefighter deaths and injuries.

An added danger for the firefighter exists in the fact that, in some cases, the fire service has adopted protective equipment intended for other industries, since equipment specifically designed for firefighters is not available. Examples of this can be seen in reports of in-depth investigations of deaths and injuries directly related to the use of boots, breathing apparatus, industrial work gloves, miners lamps, etc., that were intended for use in a relatively controlled industrial workplace as opposed to the hostile fire environment.

Unknown Nature of the Work Environment

A serious deterrent to improvements in protective equipment design has been the lack of an accurate assessment of the hazardous environments in which firefighter protective gear is expected to perform.

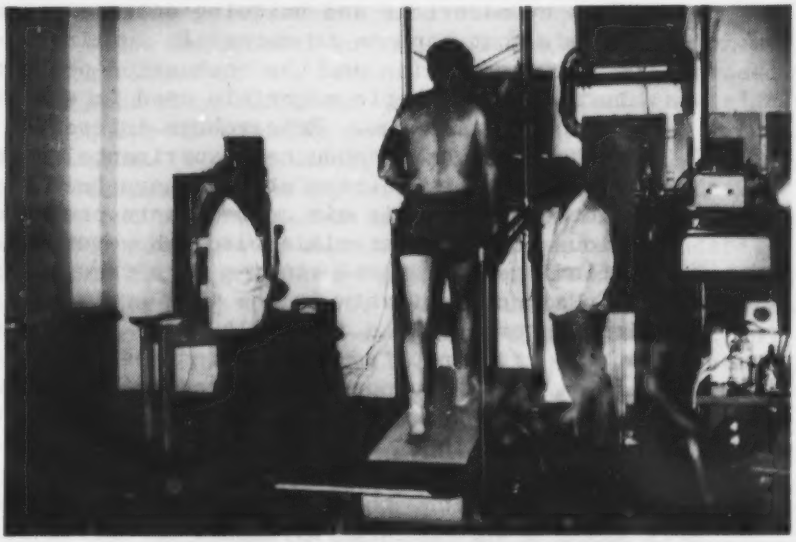
For more than a decade there has been an increased effort by materials and building science researchers to study what happens to materials in fires -- the thermal degradation and the combustion products of both natural and synthetic materials used in structures and interior furnishings. Researchers interested in modeling fire behavior have conducted experimental room and building "burns." These studies have been very useful in identifying toxic air contaminants produced when various building materials burn. However, the translation of findings from these studies into the identification of toxic air contaminants in the work environment of the firefighter has been difficult since the experimental "burns" are conducted in isolated space and do not reflect the influence of surrounding structures, wind, weather, and the unique combination of contents of each burning building.

In addition, the thermal environment of the firefighter's work area is difficult to characterize. In industrial settings the parameters of the thermal environment can be identified. When these measurements are considered with an assessment of metabolic work rate, the long term effects of heat can be pinpointed and appropriate protection provided. In the firefighting environment, however, the proximity to flames with the resultant high rates of heat transfer and the unpredictable mobility of the firefighter on the job further complicate an assessment of the thermal environment encountered. Consequently, information necessary for the design of equipment capable of adequately protecting the firefighter from the ravages of his work environment does not exist.

Inadequate Physical Fitness Programs

Firefighting requires an above-average level of fitness. This is documented and well recognized throughout the fire service. Most candidates for the job of firefighter are screened to ensure that those entering the profession are not likely to be susceptible to physical or mental stress. In almost

all departments, prospective firefighters have to pass some type of medical examination, but the requirements vary widely throughout the country. However, once a person is accepted as a firefighter, follow-up medical check-ups, even in some of the best departments, vary from none to sporadic to annually.



A recently completed study, sponsored by USFA, to determine the physical capabilities needed in the job of the firefighter, concluded that "The successful completion of firefighting tasks requires a physical performance profile reflecting youth, high aerobic capacity, high muscular strength and endurance, above-average lean body weight, and minimal body fat."[6] This conclusion was based upon the scientific analysis of cardiovascular and pulmonary responses obtained from a sampling of professional firefighters from six departments during the performance of simulated firefighting tasks. The study revealed that as many as two-thirds of the firefighters sampled did not meet the physical performance profile necessary for the successful completion of expected firefighting tasks.

The demands of the job are such that a rigorous fitness program is of primary importance to raise and maintain sharpness. Yet only recently have many fire departments become interested in establishing on-duty physical fitness programs for their members. In some cases these are well designed programs which actually match exercises with firefighting tasks.

However, in the large majority of depa
programs are still just general sports
which may help to maintain general phy
but do nothing special to prepare the
the actual rigors of the job -- prepar
could be crucial to the firefighter's

Staffing and Scheduling Policies

The size of crews responding to
firefighter safety and health. Some
and acute diseases, such as sprains a
may occur more frequently when crew s
forcing individual firefighters to ha
or greater loads than they are physic
handling. Smaller crew sizes also ma
for firefighters to prevent injuries
for each other, through the use of th
or specially designated safety office
hand, smaller crew sizes may reduce t
injuries due to fewer exposures. For
number of injuries due to sudden expl
collapses, or smoke inhalation may in
number of people sent into the fire i

Other staffing and scheduling po
affect firefighter safety and health.
shift, for example, may produce a cum
effect that would make injuries more
final hours of the shift. On the oth
shift will also mean a longer off-dut
48 hours) between on-duty periods. S
sprains may be largely healed after 4
off but not after 16 hours of off-dut
available to a firefighter working an
An earlier return to duty could re-ag
and delay recovery.

Research on the effects of staff
scheduling has been very limited to
not yet provided clear enough eviden
fighter injury and disease rates in
policies. There have been some notab
the area. One set of field simulatio
the Dallas Fire Department in 1969,[7]
three-man crews become fatigued near
of collapse in the process of moving
fight fires on upper floors. Anothe
by the Seattle Fire Department in 19
the frequency and severity of injuri
making use of the city's variable ma

in which company size ranged from three to six firefighters. Like the Dallas study, the Seattle study found some evidence that small crew sizes meant more severe injuries.

Inadequate Safety Training

Training, or lack of training, also can have an effect on firefighter deaths, injuries, and disabilities. It is generally accepted that training is the key to performance. Currently, however, the emphasis in firefighter training is on suppression, not on safety and health. Greater emphasis on safety and health training, whether it be in the proper use and care of protective equipment and breathing apparatus, use of firefighting tools, signs of building collapse, signs of unusually toxic environments, etc., is a must to successfully reduce deaths and injuries. Some safety and health training is available, but at both the state and local levels it ranges from excellent to non-existent. Usually economic considerations influence the quality of the training available, but another factor is lack of knowledge about effectiveness of safety and health training techniques and specific programs. Information about techniques and programs does exist, but the fire service does not have a system for exchanging such information.

Inadequate Information Exchange

In spite of the information that appears in fire service magazines and professional journals, conferences, and workshops, there is still inadequate interchange of technical information among fire departments and from other sources to fire departments. Much that is published is the result of individual efforts on a piecemeal basis and does not reflect a systematic interchange of information about the results of newly developed programs, deficiencies in equipment, evaluations, etc. As a result, many fire departments continue to use deficient equipment or procedures and outmoded apparatus and tools, because they are not aware that something better exists.

This lack of a comprehensive, systematic, and rapid method of disseminating information is a contributing factor to the high rates of deaths and injuries in the fire service. We believe that many could be avoided with a better-informed fire service community.

Inadequate Firefighter Casualty Data

It is impossible currently to assess the full impact of the factors affecting firefighter safety

and health, because of the inadequacy of the data which is currently collected on firefighter deaths, injuries, occupation illnesses, and disabilities. There are few sources of data, and the limited data which is available lacks sufficient detail for identifying specific factors contributing to the large number of firefighter deaths, injuries, and disabilities each year. Often, the data collected is not available on a sufficiently timely basis for identification of even the major safety and health problems of firefighters. (As illustrated on pages 22-28, the most recent data available is for 1978.) Further, the available data may or may not represent the total experience of firefighters nationwide.

Currently, available data gives rough estimates of the number of firefighters being killed and injured each year, and a general picture of where and how these deaths and injuries occur, and what types of injuries are being incurred. For example, data indicates that the majority of firefighter deaths and injuries during 1978 occurred at fires in residential properties, the greatest fraction of firefighter deaths were caused by heart attacks resulting from stress, and the greatest fraction of injuries were the result of falls and being struck by or having contact with hazardous objects. We do not have sufficiently detailed information about the incidents and the sequences of events which resulted in firefighter casualties to identify specific safety and health problems, i.e. -- information about where the firefighter physically was at the scene; exactly what the firefighter was doing at the time of injury; details about causes and types of injuries incurred and the relationship of the firefighter's protective clothing and/or equipment to those injuries.

Further, we do not know yet if the firefighter casualty picture for 1979 is the same as the picture we have for 1978. And because of the limitations of the systems for collecting this data, we do not know definitely that the 1978 data represents what is happening nationwide. The national data collection efforts and the type death, injury, and disability data that is available from these sources is presented here to illustrate the need for better information.

SOURCES OF DATA

USFA's National Fire Data Center began collecting fire incident-related firefighter casualty data in 1976 through its National Fire Incident Reporting System (NFIRS). NFIRS data is collected by local fire departments and reported through the State Fire Marshal's

Office in participating states. By 1978, 15 states had collected and reported a full year's data; by the end of 1979, 17 had. Although not every department in these states reported to NFIRS, the amount of data collected still provides basic information about the big parts of the problem. NFIRS uses the National Fire Protection Association's (NFPA) 901 Uniform Coding for Fire Incident Reporting. The data gives general information about when, where and how deaths or injuries occur. It does not provide information on the situation in which the firefighter was killed, injured, or disabled; where the firefighter was when injured; exactly what the firefighter was doing at the time of the injury; and details about causes and types of injuries necessary to relate the injuries to training, experience, physical condition of the firefighter, or tactics. Nor does it provide any information about the firefighter's protective clothing or firefighting equipment which can be related to the injuries.

Another source is the annual report on firefighter deaths and injuries published by NFPA in its journal, Fire Command. NFPA collects its information on firefighter casualties, along with data on the total number of fires, dollar losses, and civilian casualties, by surveying a nationally representative sample of fire departments. This information is also organized according to the NFPA 901 Codes and, consequently, has the same limitations as NFIRS data. In addition, the representativeness of the NFPA firefighter injury data is not known because the injury experience of the non-respondents to the survey (about 64 percent) is not known yet.

The Law Enforcement Assistance Administration's Public Safety Officer Benefits (LEAA-PSOB) program is currently the major source of the most detailed information on firefighter deaths from fire departments throughout the country. The information required for the public safety officer's death benefit award of $50,000 includes a detailed description of the incident in which the death occurred, as well as a copy of the officer's related medical records and death certificate. Because of the specific limits on individuals covered, however, records on some firefighter deaths are never submitted. For example, an on-duty heart attack is covered only if there was an accompanying fire injury sufficient to have caused the attack, such as a case in which the levels of carboxyhemoglobin in the blood at death indicated that the firefighter was downed by

carbon monoxide poisoning. Further, if the firefighter had no dependent, there is no eligible beneficiary and complete documentation of the death is not filed. In addition, although the LEAA-PSOB program began in September 1976, information regarding the program apparently has not reached all fire departments. As late as October 1979, some early 1977 deaths were just being reported.

When the limitations on types of deaths covered by the LEAA-PSOB program and the requirement for a dependent beneficiary at the time of death become more widely known throughout the fire service, it is possible that fewer firefighter deaths will be reported to LEAA. Therefore, an alternate source of the detailed data for in-depth analysis needs to be established now.

NFIRS and NFPA use data on firefighter deaths from the LEAA-PSOB program. However, this information also is organized according to NFPA's 901 Codes for publication and the detail needed for pinpointing firefighter safety and health problems is lost.

A long-standing, important source of death information on paid firefighters is the International Association of Fire Fighters (IAFF). It annually publishes aggregate statistics on the number of firefighter injuries and deaths collected by survey of its member fire departments. Its information is also collected and published in general, overall categories such as fireground smoke inhalation, strains and sprains, etc., and therefore provides no more detail than NFPA or NFIRS data. Again, because of lack of information from departments not responding to the survey (about 50 percent in 1978) the data may be biased towards the types and frequencies of injuries and deaths that occur in the responding departments.

The IAFF information on occupational disease retirements is the only published national information on occupational diseases in the fire service. Based on that information, we know that there are a large number of disability retirements due to heart and lung diseases each year among IAFF members. No similar data exists on non-members.

From these existing data sources we can provide gross summary facts about where, when and how a significant fraction of the Nation's firefighters are being killed and injured. But because the latest year for which we have even these facts is 1978, we cannot be sure that our actions today strike at today's problems. And we do not have the detail

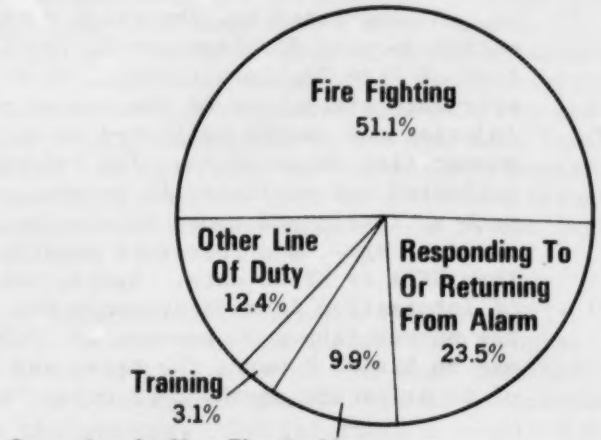
and confidence in the data needed to formulate and track remedial programs as efficiently and accurately as we could.

CURRENT FIREFIGHTER CASUALTY DATA

WHERE DEATHS OCCUR

According to NFPA's published analysis of LEAA data, together with an in-depth follow-up with the involved fire departments, just over half of all on-duty firefighter deaths (51.1 percent in 1978) occur at the fireground (see Figure 1).[9] Off the fireground, firefighters are most frequently killed in motor vehicle accidents -- usually responding to or returning from an alarm. During 1978, 23.5 percent of these firefighter deaths resulted from such incidents.

FIGURE 1: FIREFIGHTER DEATHS BY TYPE OF DUTY, 1978



Total 162

Source:NFPA

As in the past, most fireground deaths in 1978 occurred in residential fires (see Figure 2). That is due in part to the fact that most structural fires are residential fires.

FIGURE 2: 1978 FIREFIGHTER FIREGROUND DEATHS BY PROPERTY TYPE

(% of Total Fireground Deaths)

PROPERTY TYPE	TOTAL	PAID	VOLUNTEER
Residential	47.0%	56.1%	38.1%
Stores	14.5	17.1	11.9
Vacant Buildings	10.8	17.1	4.8
Grass, Brush, Forest	10.8	4.9	16.7
Storage	8.5	0	16.7
Highways, Bridges, Railways	6.0	2.4	9.5
Nursing Homes	1.2	0	2.3
Clubs	1.2	2.4	0
Total	100%	100%	100%

Source: LEAA

HOW AND WHY DEATHS OCCUR

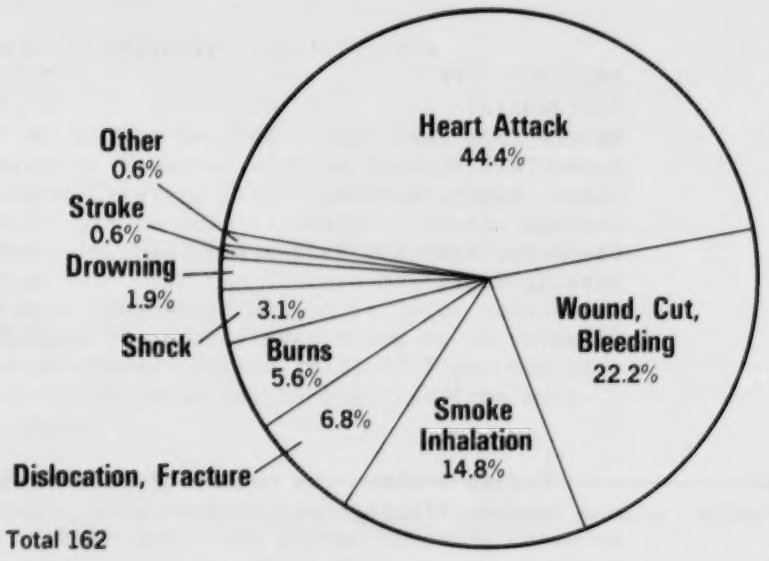
Figure 3 shows the nature of fatal injuries -- how on-duty firefighters died in 1978. Most (44.4 percent) of these deaths were from heart attacks. Wounds, cuts, and bleeding, including internal injuries and bleeding resulting from motor vehicle accidents, collapsing roofs and walls, etc., accounted for more than 22 percent of the fatal injuries.

Figure 4 indicates the causes -- why on-duty firefighters died. The largest number of these deaths were caused by stress which produced heart attacks. Although comprehensive studies of heart disease in firefighters have not been conducted, several studies of on-the-job stress response, i.e., increased heart rate, adrenalin, catecholamine output, and the effects of carbon monoxide inhalation on development of cardiovascular disease, do indicate a direct relationship between firefighting and development of heart disease.

The second most frequent group of causes of firefighter deaths in 1978 were falls, being struck by objects, and contact with hazardous objects.

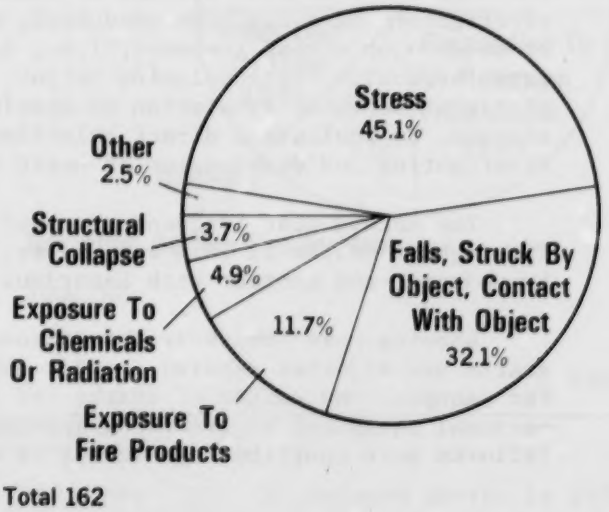
Knowing more precisely the reasons for firefighter deaths and injuries remains a major gap in existing information. For example, the number of deaths and injuries in which personal equipment -- breathing apparatus or helmet or boots -- failures were contributing factors is not known.

FIGURE 3: NATURE OF FATAL INJURIES TO FIREFIGHTERS, 1978



Source: NFPA

FIGURE 4: CAUSES OF FIREFIGHTER DEATHS, 1978



Source: NFPA

DEATHS: VOLUNTEER AND PAID

We cannot accurately estimate the rates of deaths to paid or volunteer firefighters for two major reasons: First, there are no accurate figures on the total number of volunteer firefighters or the total number of paid, full-time firefighters in the United States. Best available estimates put the current number of active volunteers at approximately 500,000 (with roughly 350,000 more who are social or inactive volunteers) and the number of paid, at 267,000. Of the paid service, approximately 200,000 are full-time paid firefighters and officers. There are approximately 67,000 part-time paid firefighters that are equivalent to 3,000 full-time paid firefighters. Second, estimates based on samples of departments have not adequately included checks on the profiles of those not responding. Consequently, we cannot say precisely what the rates of deaths (or injuries) are for each group, though we can approximate and we can consider their different problems.

Available data on deaths of volunteers does show differences in the magnitude and nature of their problems from those of paid, full-time firefighters. More volunteers die on the job than paid firefighters. According to NFPA's published analysis of LEAA data, 93 volunteers died in 1978, and 69 paid firefighters were killed. In addition, the number and proportion of deaths from heart attacks were higher for volunteers in 1978 -- 45 versus 28 for paid firefighters. Fifteen percent of the volunteer heart attack victims were firefighters under the age of 40 while only 4 percent of the paid firefighters were. It is generally known that physical health requirements for entry into the volunteer service are not as stringent as those for entry into the paid service, and these figures may indicate that volunteers are, therefore, more suceptible to on-duty heart attacks. In addition, beyond the age of 55, deaths of paid firefigheres begin to drop off in relation to deaths of volunteers. This may be due to the fact that paid firefighters retire around the age of 55, while many volunteers continue to serve.

More volunteer firefighters were killed riding the fire apparatus to or from an incident than were paid firefighters. Just over 9 percent of paid firefighter deaths occurred in this type incident, while 16 percent of the volunteer firefighter deaths occurred in such incidents. Of the volunteer firefighters killed responding to or returning from an incident, 26 percent were driving their own vehicles. Possible explanations for much of the difference in risk between the two groups are 1) that some volunteers are probably not as well trained to handle fire apparatus, 2) that some volunteers respond to fewer incidents and therefore get less actual experience, 3) that many volunteers often respond over much greater distances on country roads at greater speeds, 4) that many travel in vehicles not easily recognized as emergency vehicles, and 5) that some volunteer departments use converted oil or army trucks for tankers. Twenty percent of the volunteer firefighter deaths that occurred riding fire department apparatus involved trucks know to be converted tankers.

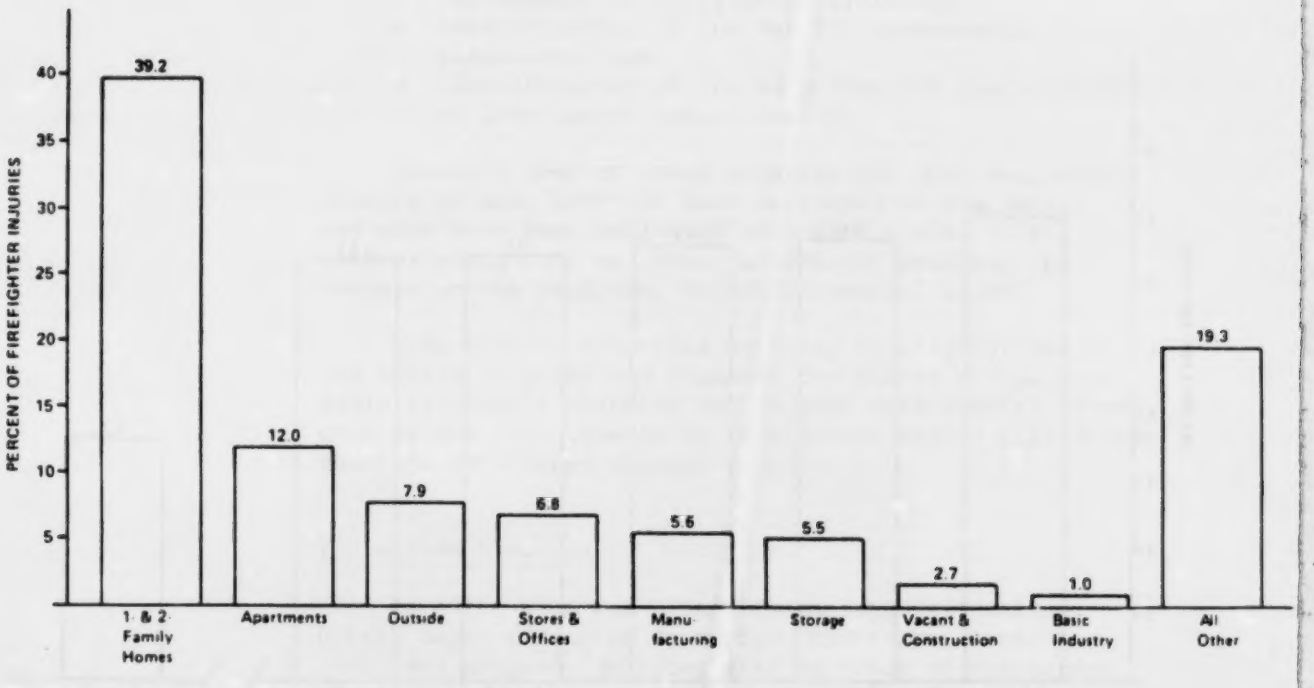
Another major difference -- generally reflecting the basic difference between the two duty types -- is that (excluding deaths from fires in residential properties) paid firefighters die more frequently at fires in stores and vacant buildings, while volunteer firefighters die more frequently at storage or grain, brush and forest fires.

These statistics demonstrate that both paid and volunteer firefighters have severe safety and health problems. Knowing the differences between the two groups can help in targeting safety programs for each.

WHERE INJURIES OCCUR

The largest percentage (66 percent) of non-fatal firefighter injuries also occur at the fire scene, and more than half occur in residential property fires (see Figure 5).

FIGURE 5: WHERE FIREFIGHTERS ARE INJURED

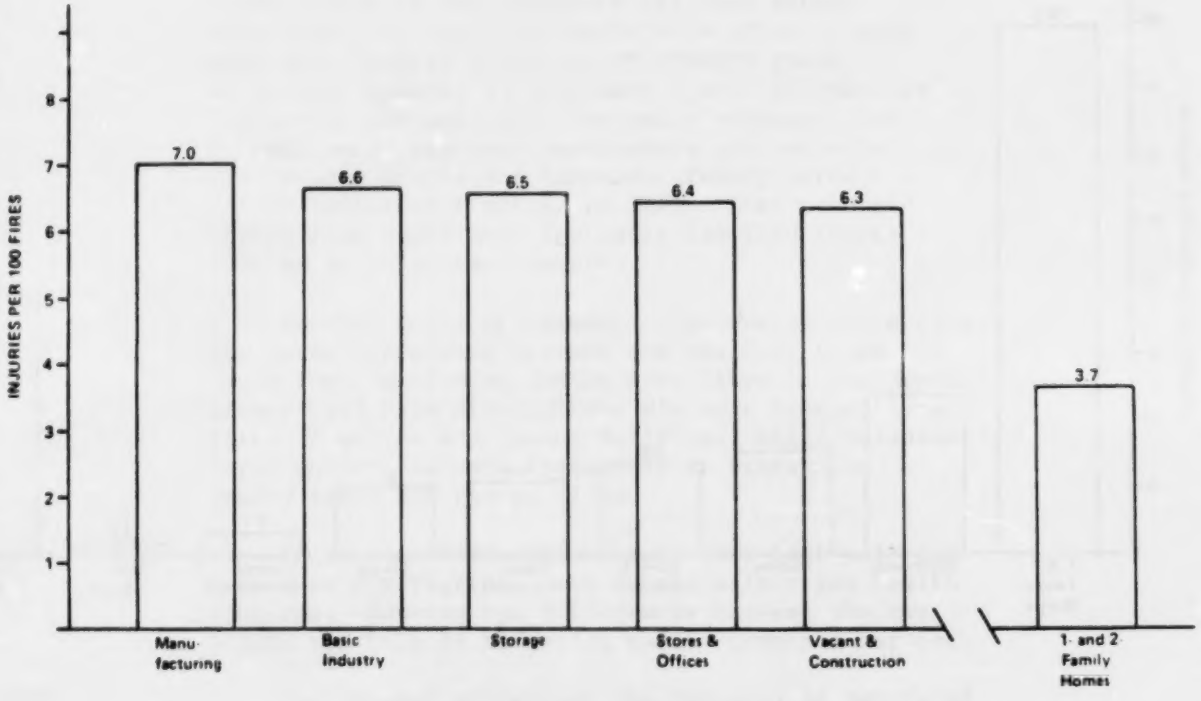


Source: USFA-NFIRS 1978

But residential fires are not the most dangerous ones for firefighters. The average number of injuries per fire shows which types of fires are most dangerous to fight. Figure 6 shows the fires in manufacturing, basic industry, storage, store/offices, and vacant/ construction properties present the greatest risk. The injury rates associated with these fire situations are nearly twice those for residential fires.

These rates are high probably because the general floor plans and contents of these properties are less familiar to firefighters than those they encounter in residences; these properties also may contain larger amounts of hazardous materials; more of the fires in these properties are large, and more are intentionally set.

FIGURE 6: MOST DANGEROUS OCCUPANCIES FOR FIREFIGHTERS



Source: USFA-NFIRS 1978

Away from the fireground, other on-duty activities, such as inspections and equipment maintenance, account for 18 percent of all firefighter injuries, according to NFPA. Ten percent are related to responding to or returning from a fire, carrying out rescue, or EMS (Emergency Medical Service) operations. And 5.6 percent of firefighter injuries occur during training.

CURRENT PROGRAMS AND FUTURE NEEDS

Current programs within the U.S. Fire Administration and other fire protection organizations are addressing known firefighter health and safety problems and focusing on:

- o development of improved protective clothing and equipment;
- o improvement of firefighter physical fitness;
- o identification of occupational health hazards;
- o improvement of firefighter training;
- o identification of the hostile environment components; and
- o identification of the magnitude and characteristics of firefighter casualties.

However, some of these programs are just beginning. Results of most have not been delivered to the field, and none have been delivered on a mass scale. Also, with existing data we cannot adequately evaluate the success of the programs, except in general terms.

This section describes existing firefighter health and safety programs and presents the United States Fire Administration's thinking on the work that remains to be done before improvements in firefighter safety will become possible on a broad scale.

Protective Clothing

In 1976, USFA and NASA's Technology Utilization Office began a program to design, fabricate, field test, and evaluate an integrated ensemble of protective clothing and equipment for firefighters. The program is called Project FIRES (Firefighters Integrated Response Equipment System).

A User Requirements Committee (URC) representing all groups in the fire service community -- fire chiefs, firefighters, volunteers, instructors, city managers, and safety personnel -- assisted in identifying the problems to be solved and establishing specific performance requirements for firefighter protective clothing and equipment.

Based on input from the URC, a detailed set of performance requirements and associated test methods were developed as part of the first phase of Project FIRES. These were the first standards ever developed for a complete, integrated firefighter's protective system.

Protective equipment currently on the market was evaluated against the new performance criteria to determine which existing items might be considered for inclusion in the FIRES "suit." In addition, the evaluation results were published to show how the then current equipment measured-up in terms of the new requirements.

An idealized firefighter's protective ensemble -- consisting of a turnout suit, helmet, gloves, and boots; a self-contained breathing apparatus; a communications system and lighting equipment -- was assembled to illustrate the amount of protection possible using advanced technology -- disregarding cost.

THE PROTOTYPE

Utilizing the performance requirements and the designated manufacturing specifications, the project team worked with the protective equipment industry to fabricate "reasonably priced" prototype ensembles using currently available materials.

Laboratory and simulated fir
been completed on the FIRES proto
totypes are scheduled to be field
later this year. Over 300 fire d
have displayed an interest in par
the field test phase of this proj
departments in four European coun
have expressed an interest in the
innovations and in the field test

The FIRES prototype includes
a full face shield which extends
upper lip. The shield is fabrica
temperature, impact-resistant gla
high-temperature-resistant thermo
can be stowed inside the helmet w
The helmet fits over a hood which
turnout coat or jacket providing
protection and preventing water a
entering the neck and ear areas.
something like that worn by race
comes in two weights for use in d

The turnout suit prototype i
designs: One consists of a short
pants; the other consists of a mo
3/4-length coat and slightly modi
Two shell materials for the suit
50/50 blend of Kevlar^{R} and Nomex^{R}
fire resistant material called Po
Fiber (PBI). To enhance the comf
a vapor barrier of Gore-Tex^{R} bon
check" material forms the middle
While water cannot penetrate the
use of the material reduces the p
heat exhaustion because it does a
perspiration to pass through and
and allows air to get in. A th
quilted batt completes the suit.

The prototype ensemble also
two newly-designed gloves and an
light-weight boot with added sid
and improved arch support. To c
"envelope" effect, a wristlet th
palm can be attached to the slee
turnout coat or jacket and boot-
to trouser cuffs to totally seal
water.

The final design for the prototype offers firefighters increased protection, increased mobility, and a 40 percent reduction in weight. The current projected price is 25 to 30 percent above that of today's gear, and will total about the cost for a man's business suit, a pair of shoes, and a hat.

A study is currently underway to determine the total cost cities are experiencing from firefighter casualties to enable local governments to compare the longer range savings they can expect against the immediate outlay for these improved protective suits.

Guidelines for purchase specifications that can be adapted to the needs of any fire department are being prepared. They will be published by the Fire Administration during the coming year. For the field-tests, about eight to ten fire departments across the country will use protective clothing fabricated according to the Project FIRES standards and specifications to determine how it stands up to demands in a working fire department.

During the development of the FIRES suit there have been off-shoot benefits: interaction between the project team and industry has stimulated the transfer of technology which will ultimately lead to the private sector offering other improved protective equipment to the fire service in the near future. Some examples of this include:

- o helmet manufacturers are working on improved helmet configurations and evaluating new materials;
- o a firm is attempting to adapt some advanced composite materials to the development of improved firefighter helmet shells;
- o a recently developed extended-duration breathing apparatus is currently being evaluated by another firm;
- o an industrial products firm is adapting a light-weight boot, developed for the military, for fire service use;
- o work has begun to adapt a new material, which allows perspiration to evaporate but prevents moisture penetration, for use in the manufacture of protective clothing;

- o new blends of fabrics, more efficient for turnout coats than currently available materials, have been developed; and
- o data from Project FIRES is being used by a firm to determine the need for a $10 million plant for the manufacture of a particular fire-retardant fiber.

To further stimulate the orderly transfer of the technology developed during the earlier phases of the project, industry briefings have been scheduled to allow for the first-hand dissemination of Project FIRES results to date to potential suppliers of the field-test ensembles. The first briefing was held in Los Angeles on February 28, the second in New Orleans on March 13, and a third in New York on March 27, 1980.

To provide the fire service with improved protective clothing and equipment and to enable voluntary and regulatory standards-making organizations to promulgate protective clothing standards, based on these research and development efforts, which include performance criteria, test methodology, and complete evaluations of the equipment in actual firefighting use, the following would need to be accomplished:

- o Complete field tests and the evaluation of improved firefighter protective clothing developed under Project FIRES including any modifications needed as determined by the field tests, and their subsequent evaluation.

- o Complete the design, manufacturing and purchase specifications, and recommended performance standards for the totally integrated protective clothing and equipment in the Project FIRES system.

- o Develop and conduct improved product awareness programs to stimulate more rapid utililzation of advanced technologies in the area of firefighter protective clothing and equipment.

HAZARDOUS SPILLS PROTECTION

There is also increasing demand from the fire service to adapt clothing and equipment to protect firefighters called on to conduct rescue and control operations at incidents involving hazardous materials. To accomplish this, it will be necessary to determine the degree of protection against "typical" hazardous materials afforded by currently

available protective clothing and equipment, including the Project FIRES ensemble, and to determine modifications needed to provide improved protection.

STANDARDS AND PERFORMANCE CERTIFICATION

The cooperation of the sponsors of research and development efforts, such as USFA, and the consensus standards-making organizations, such as the National Fire Protection Association (NFPA) and the American National Standards Institute (ANSI), is a necessary ingredient in the development, promulgation, and acceptance of firefighter protective clothing and equipment standards. Even though these standards are meant to be used on a voluntary basis, they represent the consensus of active members of the fire service community and are frequently referenced by law in Federal, state, and local regulatory standards.

The resources for the development of voluntary standards are limited. Therefore, organizations like NFPA and ANSI must depend on others for the research and development efforts on which to base standards criteria. For example, the National Bureau of Standards (NBS) sponsored research to develop design criteria for turnout coats, and that research was the basis for an NFPA standard for firefighters' turnout coats and trousers promulgated in 1975. More recently USFA and NBS conducted research, and USFA recommended a standard for structural firefighters' helmets. That recommended standard was used by NFPA as the basis of its helmet standard. The USFA-inspired standard also is referenced in the Federal OSHA Fire Brigade Standards and in the California OSHA Standards for Municipal Firefighters' Protective Equipment.

Information on current standards, specifications and advancements in firefighter protective clothing and equipment is rarely accessible to fire departments at the time when they need it most - when purchasing new clothing and equipment.

To aid departments and other purchasers of firefighter's gear, the USFA compiled a guide, Protective Clothing and Equipment for Firefighters: Current Standards and Practices. This document, which has been widely used, provides an assessment of the state-of-the-art in protective clothing and equipment and describes relevant standards which fire departments can use in developing purchase specifications.

Research and development to establish standards for new and improved firefighter equipment will continue, particularly within USFA. But these standards cannot be effective as they might be as long as there is no centralized, unbiased program available to certify that the performance criteria and design specifications are being met.

The Mine Safety and Health Administration (MSHA) and the National Institute for Occupational Safety and Health (NIOSH) provide the mining, construction, electrical, and other industries with rigidly enforced certification programs for protective clothing and equipment used by those industries. Even though the Federal OSHA's Fire Brigade Standards for Protective Clothing and Equipment are in the process of becoming regulatory, there are no established procedures for the certification and approval of firefighters protective clothing and equipment.

The one exception to this was the establishment of a joint OSHA/NIOSH/MSHA Committee to propose revisions to the certification and approval schedules for respiratory protective devices. This action was initiated as a result of the fire service's -- especially the International Association of Fire Fighters -- participation in a public hearing on this subject held by NIOSH in November 1977. USFA assisted the Committee to develop recommended certification and approval schedules, but these proposed revisions have not appeared for public comment. It seems unlikely, as a result, that the revised schedules could be put into effect for some time.

But we must ensure that firefighters have access to safe clothing and equipment which meets the requirements of accepted design and performance standards as well as developing a reliable certification program.

Breathing Apparatus

In an attempt to provide more serviceable respirator protection for firefighters, USFA is beginning to investigate the use of closed-circuit breathing apparatus (re-breathers). These devices circulate oxygen-enriched air from tank to firefighter and back again, scrubbing carbon dioxide out and taking no air in from the outside. Closed-circuit systems are relatively light, less bulky, and longer-lasting than the open-circuit systems currently in use. Most re-breathers, however, have been designed for industrial or mining use and are not usable in the firefighting environment.

To improve breathing apparatus available to firefighters, one approach might be to evaluate existing re-breathers during the upcoming Project FIRES field tests and, based on that evaluation, encourage the breathing apparatus industry to make modifications necessary to meet firefighting needs.

Ancillary Protective Equipment

Although the specifics are different, the circumstances involving fireground communications systems, personal lights, and personal emergency warning devices are similar to those involving respirator devices. The technology is available to be transferred. In many cases it is a matter of adapting existing equipment and devices to answer the specific needs of the fire service. Of particular concern, because of the increasing frequency of hazardous spills and fires involving toxic chemicals, is the need for a device which could analyze the atmospheric environment at the fire or spill scene.

In order to stimulate the industry to transfer that technology, existing models must be tested and evaluated in light of firefighter needs, and less expensive models must be developed.

Specific actions that would be required to accomplish this are:

- Develop and field-test a reasonably-priced personal communications system, integrate with Project FIRES.
- Develop and field-test personal distress alarm devices, integrate with Project FIRES.
- Develop and field-test personal lighting devices, integrate with Project FIRES.
- Modify and field-test space technology instrumentation to provide a toxic environment detection device for use at the fire or spill scene.

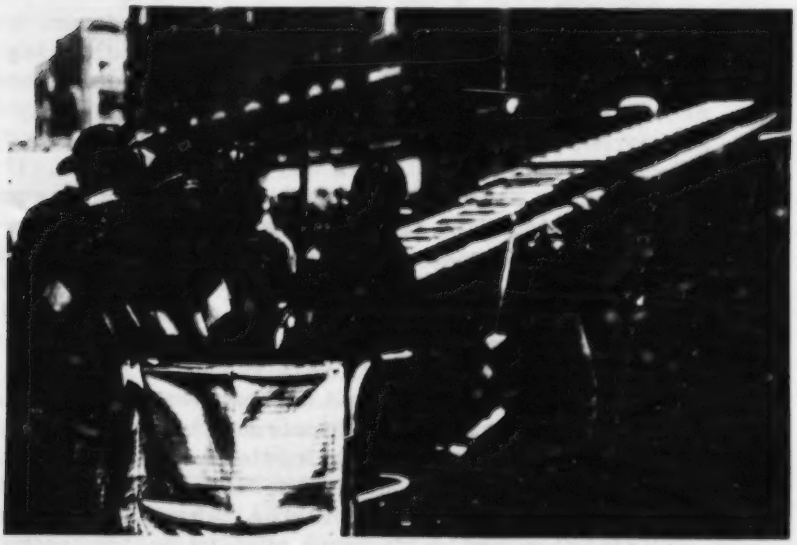
Firefighting Tools

Earlier, reference was made to the fact that the firefighter uses tools in his job which have not been changed in design or materials for generations. The reasons for the failure to use advances in technology

to improve firefighting tools are similar to those in the area of protective equipment. Thus far there has been little if any activity to even identify the requirements in firefighting tools. There is a need to determine what deficiencies exist in tools and auxiliary equipment, such as used by structural firefighters, and to assess the magnitude of the problem as it relates to health and safety.

The User Requirements group from the fire service community that advises the Fire Administration should expand its area of responsibility beyond protective clothing to identify the firefighting tools that need improvement to increase safe and efficient firefighting; identify existing technology that can be used to correct the problems pinpointed; and develop a realistic program plan for future activities in the areas of improved firefighting tools and auxiliary equipment.

That done, at a future date it would be possible to recommend specifically what needs to be done in this area.



The Firefighting Environment

As discussed earlier, researchers have studied and reported on the physiological implications of exposure to temperature extremes. This information is necessary for a better understanding of the causal factors in firefighters' occupational diseases and to map out prevention and control strategies.

USFA conducted a program to obtain information about the radiant heat load encountered by firefighters. In the study, conducted in Boston, firefighter turnout coats were fitted with instruments to measure the radiant heat environment of actual fires. At the scene of the fire, the firefighter receives radiant heat from open flames and from hot walls and ceilings. Data collected in the study was used to develop performance requirements for protective clothing and equipment during Project FIRES.

However, radiant heat is only one component of the thermal environment encountered by firefighters. Heat transfer in the fire environment is the result of conduction and convection, as well as radiation.

Conductive heat transfer occurs when firefighters' protective clothing or equipment comes in direct contact with a hot object such as the floor, a stove, or a wall. Convective heat transfer occurs when hot gases or vapors pass over protective clothing or equipment. Typical examples of convective heat transfer in the fire environment include exposure to hot combustion gases, hot air, steam, and direct flame.

The parameters of all three components must be measured before technological advances in materials and equipment design can be adapted to provide better protection for firefighters.

The same is true concerning the toxic environment of structural fires. As a result of the initial efforts sponsored by the Fire Administration to characterize the air contaminants in structural fires, there is now evidence that the toxic environment in real fires may be different than that observed in combustion products experiments conducted in the laboratory. During the initial study, also conducted in Boston, samples of air from actual fires were taken and analyzed. The study confirmed earlier research indicating that carbon monoxide, which causes anoxia by rapidly displacing oxygen in the blood, is the most common

toxic gas produced in fires. Even low concentrations of carbon monoxide can impair judgement, visual acuity, and decision-making -- all crucial to the survival of the firefighter.

But perhaps one of the most important findings of the study is that for the first time acrolein -- a highly irritating, toxic aldehyde often a product from the burning of wood -- was identified in life-threatening concentrations at the Boston fires. In over half the fires analyzed for acrolein, the short-term exposure level, or STEL, was well above the allowable limit. (Used by industry as a standard measure in safety and environment studies, STEL equals the greatest contaminant concentration an unprotected worker can be exposed to before suffering physical harm.)

Nontrivial concentrations of nitrogen dioxide, hydrogen chloride, hydrogen cyanide, and benzene also were found. Previous studies have shown that inhalation of these irritants along with carbon monoxide, especially when suspended with particles in air, is hazardous even when concentrations of the individual gases are below the STEL.

The study also makes it apparent that firefighters have no way of determining if toxic gas concentrations are present at a particular fire, reinforcing the need for respiratory protection at all fires. The findings show that many structural fires in Boston have toxic levels of some substance, guaranteeing that a firefighter is likely to encounter dangerous levels in about 4 out of every 10 structural fires in that city. The reported results of this initial study were influential in the issuance of a mandatory mask rule by the Boston Fire Department. During the first year under this rule, the Department experienced an 80 percent reduction in firefighter smoke inhalation cases.

While acknowledging this study's importance, USFA recognized that it was limited to the collection and analysis of air contaminants primarily during fire suppression activities and that a profile of the atmosphere from the ignition through the suppression and the overhaul phase of fire incidents is needed. Also, the fires in other parts of the country may differ due to different construction, furnishings, etc. USFA is continuing support of studies to increase the geographic scope and the depth of the investigations in this area.

In Cincinnati, USFA is providing technical assistance for a study by the Cincinnati Fire Department and National Institute for Occupational Safety and Health (NIOSH) which began last fall. They are investigating atmospheres faced by firefighters at actual fires, paying special attention to toxic air contaminants remaining at dangerous levels during overhaul operations. Gases produced at different stages of structural fires will be compared to provide a broader, more detailed picture of the causes of air contaminants, as well as the varying degrees that smoke is diluted during the life span of a fire.

Another study of toxic air contaminants encountered by firefighters was launched this spring by Southwest Research Institute of San Antonio. Funded by USFA and the Society for the Plastics Industry, Inc., of New York, the researchers plan to obtain more specific information about fire development, materials burned, and potential physiological effects of the contaminants that are identified.

These studies represent the first efforts to identify the actual air contaminants the firefighter encounters while fighting structural fires. This information is needed to provide the criteria necessary to develop performance standards for firefighters breathing apparatus. These standards in turn will provide the incentives for the breathing apparatus industry to advance the technology in respiratory protective devices to specifically address the needs of the firefighter.

It is necessary to continue and expand on existing studies being conducted to identify the actual environment faced by the firefighter during rescue and firefighting operations. This includes measuring the parameters of the total fire environment including the aspects of toxic air contaminants, temperature, visibility and sound.

Improved Medical Treatment

On the scene first-aid as well as longer term treatment protocols need to be developed for the firefighters most common, serious injury -- smoke inhalation. The exact medical nature of this injury is not understood at present, particularly the effect of multiple exposures. Furthermore, it is believed that the first aid received on

the fireground is of critical importance in long term recovery.

The hostile environment of a fire contributes to another major health hazard for firefighters -- stress. Studies of psychological stress associated with disasters, principally done on the general population, have shown stress to be a major precursor of many diseases. In a disaster, firefighters are usually the first ones on the scene and conduct rescue and firefighting operations under intense psychological-stress conditions.

Psychologists who studied the recent aircraft disasters in San Diego and Chicago reported that many of the firefighters who responded to those incidents were not psychologically prepared to cope with the situation.

The steps necessary to obtain a better analysis of the firefighting environment and its impact on firefighters' safety and health and to begin to deal with the stress problem are:

- Conduct firefighter smoke inhalation study to determine the medical/physical effects of inhalation of carbon monoxide, acrolein, and other toxic gases frequently occurring in the fire environment. Such a study should include effects of repetitive exposures, exposure both during the fire and during overhaul operations. Treatment protocols should be developed based on study results for on the scene first aid measures as well as long-term treatment.

- o Develop physiological indices of exposure of the firefighter to stress, toxic environments, and other causal factors.

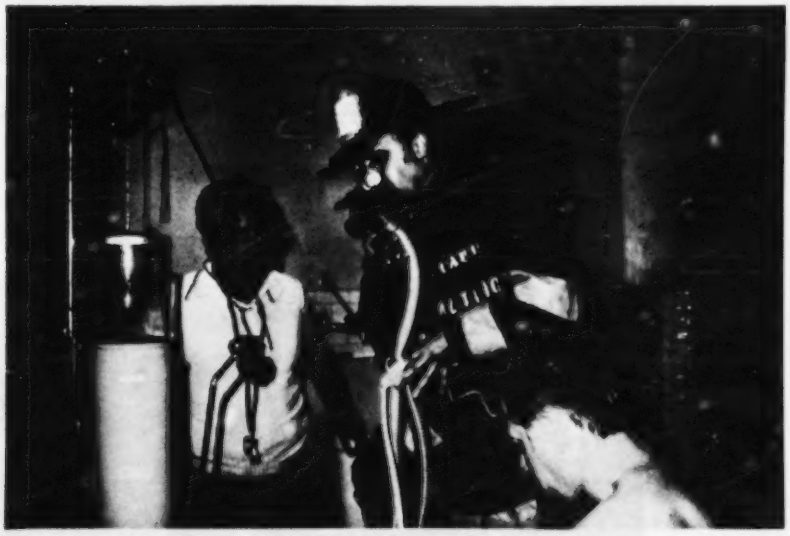
- o Develop programs in stress management to help firefighters improve their abililty to cope with the intense psychological stresses associated with firefighting, rescue, and disaster operations.

Occupational Health Hazards

There has been some attention directed toward occupational health hazards in the fire service. However, the data that has been collected exhibits little uniformity and has been subjected to limited statistical analysis. Effective strategies for prevention and control of illnesses and injuries among firefighters cannot be designed, implemented, and evaluated without a detailed knowledge of the exact consequences of duty in the fire service. Also, epidemiological investigations must be designed to answer specific questions regarding the degree and distribution of injuries, illnesses, and specific causes of deaths in the firefighter population. The USFA has initiated a program to identify both the types of acute injury and the long-term chronic diseases that occur in the fire service. When this is completed the long-term plan is to set priorities for the development and implementation of prevention and control strategies for use by fire department physicians, particularly in the area of early warning indicators of occupationally-related chronic diseases.

Fire departments are being encouraged to deal with these problems. The IAFF/USFA co-sponsored Symposia on Occupational Health and Hazards in the Fire Service, in addition to promoting physical fitness, serve as a forum for notifying the fire service of new research findings on safety and health problems in the field. Further, it is expected that the results of the study to determine the cost of firefighter deaths and injuries to the communities, mentioned above, will motivate fire departments and communities to place added emphasis on the establishment of more effective safety and health programs.

But the fire service needs a much better assessment of firefighter health hazards, as well as guidelines for improving safety and health programs. Especially needed are epidemiological investigations of occupationally related diseases in the fire service, comparison of these data to the general population, functional tests which can be used as early warning indicators of chronic diseases among firefighters, and improved data collection so these problems can be traced over time and mitigation programs evaluated.



Physical Fitness of Firefighters

The firefighter's working environment is like that in no other industry. The strenuous demands of the job require an above-average level of fitness to perform required duties effectively.

An important series of events that have stimulated interest in physical fitness in the fire service has been the Symposia on Occupational Health and Hazards in the Fire Service co-sponsored by the IAFF and USFA. During these bi-annual symposia, started in 1971, noted researchers and physicians have reported that a well-constructed, mandatory physical fitness program should be part of every fire department's daily activities, as a precaution against heart disease, back injury, and other occupation-related diseases and injuries.

However, to date there have been few such fitness programs implemented. In a study conducted for USFA it was noted that of more than 1,000 fire departments surveyed, approximately 70 percent did not have a physical fitness program, even though the majority of these departments indicated a strong interest in implementing one.[10] Although physical fitness is a subject of considerable interest and discussion in many fire departments, there is little understanding of what a physical fitness program should be. This study revealed that a large number of firefighters believe that the fact that they periodically fight fires is sufficient evidence they are physically fit. In addition, an equally large number of fire officers perceive a physical fitness program as nothing more than providing a few minutes each day for calisthenics.

In addition, there is relatively little data available from the few departments which have implemented programs to confirm the benefits of those programs. USFA is assisting in the evaluation of some existing programs to begin to extract that kind of information.

One ingredient common to the su
programs in existence is cooperation
the fire department management, labo
community's elected or appointed off
To provide guidelines to foster this
a course in the management of fire s
fitness programs is now being offere
Fire Academy. For this course, a gu
Guide for the Management of a Fire S
Fitness Program was developed. It i
as part of a comprehensive instructo
would also include specifics on mode
equipment needs to ensure consistenc
fitness programs throughout the coun

Finally, in the area of fitness
is a need to develop programs that e
abilities to perform various firefig
Even though the entry of women into
has been relatively limited to date,
increasing nationwide. In a recent
by USFA, it was noted that one of th
barring women from entering the fire
stringent physical performance requi
job.[11] However, exercise physiologis
that women can be physically trained
traditionally thought to be men's wo
equal opportunity for women in the f
necessary to make available any phys
training needed for the job so that
and effectively perform their firefi

Several steps would be necessary to accomplish this given the situation as it is today in this area:

- Based upon evaluations of old and new physical fitness programs, develop improved programs for firefighters to maintain the best possible physical condition to safely perform their duties in the hostile fire environment.

- Revise existing courses in firefighter physical fitness programs to include specifics of model programs and equipment needs.
- Promote the use of fitness programs through fire journals, conferences, meetings and the Nation's fire service training units.

- Develop and promote programs to prepare women to meet the physical performance requirements necessary to enter the fire service.

Firefighter Training

Traditionally, firefighter training has emphasized speed and effectiveness in rescue and suppression. Generally, firefighter safety and health matters have been given little attention. For example, courses on the selection, use, and benefits of protective clothing and equipment have been almost totally ignored. Firefighters should not have to wait until they are on the job to learn safe practices. For a firefighter,

learning from experience is extremely dangerous. Safety and health should be included in all aspects of training whether it be in emergency rescue tactics or in performing routine fire-fighting operations and USFA should assume the leading role in notifying the fire service about health programs and remedial action. The appropriate steps to make improvements in this area include:

- o Survey existing fire department safety and health programs to identify effective ways of reducing deaths, injuries, and disabilities that can be implemented immediately.

- o Develop courses on how to establish and improve firefighter safety and health training programs and disseminate them.

- o Develop and publish a fire department handbook for the selection, use, and maintenance of firefighters protective clothing and equipment.

The increase in recent years in high-rise structures for residential as well as commercial use also has created a need for more training in the safest, most efficient techniques for rescue and suppression in these buildings. To work toward this end we should identify firefighting techniques currently being used for emergencies in high-rise buildings, analyze and promote those that have been demonstrated to be most efficient and safe, and publish a set of recommended procedures to be used for training firefighters in these methods.

Expanding Firefighter Casualty Data Collection and Analysis

It is important here to reiterate that even though USFA is conducting programs to address the problems of firefighter health and safety, current data systems must be improved before we can evaluate the effectiveness of these programs and assess their impact in reducing firefighter deaths, injuries, and occupational diseases.

In addition, collection and analysis of detailed data on the nature of firefighter deaths and injuries must be improved to more effectively target programs to address failures in protective clothing and equipment, deficiencies in training, and inherent dangers in firefighting tactics.

Also, more accurate information on the number of firefighters killed, injured, and disabled each year is needed. Currently we have little information on recurring injuries and occupational illnesses with which to identify the cumulative effects of particular injuries which eventually result in disabilities. Further, we do not accurately know the total number of paid or volunteer firefighters, nor do we know the number of paid and volunteer firefighters that our current data covers. And we only know the numbers of those injuries that are reported through the available data sources, with different definitions of injury and little or no data on the severity of injuries.

In an effort to improve current data on firefighter deaths, the National Fire Data Center has collected the complete firefighter death records filed since September 1976 with LEAA and is also attempting to obtain from local fire departments sufficient information on the firefighters killed in line of duty who were not eligible for the LEAA-PSOB Program. An in-depth analysis of firefighter deaths during recent years is planned so that detailed prevention strategies can be developed.

The Fire Fighter Mortality Report, the results of an in-depth survey of firefighter deaths in 1974 and 1975, remains the most comprehensive study of firefighter deaths ever done, although the Data Center has updated some gross statistics with respect to firefighter deaths and injuries for its national estimates report, Fire in the United States. The Mortality study was sponsored by USFA and conducted by the International Association of Fire Fighters. IAFF obtained detailed information on each firefighter killed, such as age, years of service, duty assignment, and rank, plus descriptions of the incident and how the firefighter was killed. The analysis of 101 firefighter deaths known to have occurred during the study period was published in a report that pointed out incidents where poor training, tactics or communications, lack of equipment, or other specific factors contributed to the firefighter deaths and recommended specific measures be adopted to prevent future deaths from similar problems. Copies of the Fire Fighter Mortality Report have been distributed to local fire services throughout the country.

But much more comprehensive information on firefighter deaths for use in planning prevention strategies needs to be obtained. Therefore, through contact with fire departments nationwide, we should establish a system to obtain detailed, timely data on all firefighter deaths directly. This program should be a continuing project with an annual report disseminated to the fire service.

The Data Center, NFPA, IAFF, and LEAA share firefighter injury and death information. NFPA and IAFF annual survey results are integrated with the Fire Administration's NFIRS data to update national estimates of the magnitude of the problem each year. The Data Center and NFPA also share information collected on firefighter deaths identified by both LEAA's PSOB program records and IAFF records. Whenever one of the IAFF firefighters is killed in the line of duty, USFA is notified by the IAFF, and information on this firefighter can be obtained directly from the city fire department should no LEAA PSOB claim be submitted. Through daily working contacts, these organizations are cooperating to improve data on firefighter injuries and deaths so that the problems can more quickly be defined and solutions to reduce their numbers developed.

The USFA also funded an IAFF study of local firefighter injury reporting systems throughout the country. Injury reporting systems in 20 geographically-dispersed cities were examined to determine the level of information on firefighter injuries that could be obtained from their systems and the comparabililty of data from one city to another. The study indicated that firefighter injury reporting at the local level not only lacked sufficient detail for development of injury and death prevention programs within any one city, but also was not comparable from department to department.

Consequently, USFA's National Fire Data Center developed a comprehensive set of data elements which describe the situation in which an injury or death may occur, the role poor protective clothing or equipment plays in an injury, the specific activity of the firefighter at the time of the injury, the physical cause of an injury, the type and severity of the injury, the extent of medical treatment needed, and the final outcome

of the incident. Following review by IAFF, International Association of Fire Chiefs (IAFC), International Society of Fire Service Instructors (ISFSI), a number of local fire departments, and NFPA, a revised set of data elements were pilot-tested by IAFF for three months in three city fire departments.

The information gained from the IAFF pilot-test is currently being used as input to NFPA for its 1981 revisions to the 901 Uniform Coding for Fire Protection Manual. Since the coding manual is used by many fire departments in the country, as well as by USFA in the National Fire Incident Reporting System, adoption of the committee's recommendations for firefighter injury reporting data elements will upgrade both local and national reporting of firefighter injuries and deaths.

To further improve data obtained on firefighter deaths and injuries, we should expand pilot-testing of a firefighter death and injury data reporting system in two NFIRS states during FY 1981. Tests will provide information on the workability of the data elements and forms. Based on that information, USFA will evaluate the system and make necessary changes before recommending that all NFIRS states adopt it. Following that, we should support all NFIRS states in adopting the refined system for reporting all onduty firefighter deaths, injuries, occupational illnesses and disabilities. Use of such a system will provide the first detailed, nationally comparable data on where, why, and how America's firefighters are bing killed and injured.

Present estimates of the number of volunteer firefighters throughout the United States must be improved. The USFA has sponsored a survey by the National Volunteer Fire Council of fire departments protecting communities of 50,000 people or less in order to identify and characterize the Nation's volunteer fire departments. The survey will supply information on the number of volunteer departments; their age-of-firefighters distributions; the type of training firefighters receive; the type of services provided by the departments in addition to fire suppression; and kinds of incident records kept by the departments.

Preliminary results of the survey show that in the nearly 18,000 volunteer fire departments which protect communities of 50,000 people or less, the large majority of these volunteer firefighters -- about 450,000 -- serve communities of 10,000 people or less. The majority of volunteer firefighters -- 60 to 64 percent, depending on community size -- are over 30 years of age with training predominantly conducted at the department level and supplemented by State training of some type.

Currently, injury data is available only for paid and volunteer firefighters combined. Differences in the incidence, causes and types of injuries, and in the situations in which they occur need to be identified if prevention programs are to be designed to meet the needs of all the Nation's firefighters. In addition, a man-hour exposure equivalent between paid and volunteer firefighters needs to be developed in order to compare deaths, injuries, and disabilities between the two firefighter groups.

There is currently no comprehensive national source of detailed data on injuries, occupational illnesses, and resulting disabilities sustained by the Nation's firefighters. However, many states now have adopted occupational health and safety laws which require reporting and record-keeping by local fire departments of such data. These data should be collected from communities in states with the OSHA-type record keeping requirements and analyzed to identify current kinds of injuries, occupational illnesses, the frequencies with which given types of injuries and illnesses associated with the job of firefighting occur, age distributions of firefighters suffering the various kinds of injuries and illnesses, and the types of disabilities resulting from these injuries and illnesses. In addition, analysis of such data could make it possible to correlate specific injury types with the various classes of occupational illnesses and disabilities -- another tool in targeting prevention and control programs. The improved data also would provide a base from which to track improvements or lack thereof, stemming from efforts to reduce firefighter deaths, injuries, and disabilities.

Statistically reliable annual estimates of the major casualty circumstances should be produced annually and disseminated to the fire service to increase awareness of the specific problems that exist. The interim program should be continued through 1982 when it would then be possible to collect more detailed information through NFIRS.

In addition, specialized, in-depth investigations of firefighter safety and health problems identified by improved casualty-data collection should be conducted. Each of the above programs for collecting improved firefighter death, injury, occupational disease, and disability data will identify specific problems of firefighter safety and health that need specialized in-depth investigations. As these specific problems are identified, they should be thoroughly investigated, prevention measures developed, and the information disseminated to the fire service on a timely basis.

We also need more detailed information on physical requirements for entry into the fire service throughout the country; the types, intensity, and frequency of training provided; the kinds and quality of firefighting equipment in use; and the types of departmental policies and practices in existence which affect firefighter safety and health if we are to assess the impact of these factors on firefighter deaths, injuries, and disabilities.

A beginning effort to collect needed firefighter and fire department characteristics data from the departments in states currently participating in NFIRS and similar data from a representative sample of fire departments in non-NFIRS states is planned for FY 1981. An expanded effort to collect characteristics data from most departments nationwide during the following year will provide data for analyzing local-, state-, regional-, and national-level firefighter safety and health problems. With a national base of characteristics data, refined in-depth data on firefighter deaths, injuries, occupational illnesses, and disabilities can be analyzed to determine the severity of safety and health problems of various groups of firefighters, the causes of those problems at the local, state, regional, and national levels, and the preventive programs which could be developed.

What is specifically needed is to collect data on the characteristics of firefighters and fire departments in the United States to provide a more accurate base for measuring casualty rates and pinpointing problems. Information collected would include type of department (paid or volunteer); the number of firefighters protecting a given population or area; distributions of age, rank, years of service, and level of training; shifts worked; duties performed; department safety policies; equipment available and its usage; etc. This data is necessary to adequately analyze firefighter training, equipment and overall departmental manning levels in the United States and compare experience among the departments.

More research also is needed to separate the effects of crew size from the effects of differences in the kinds of fires fought, levels of fatigue and physical fitness, and other differences that affect health and safety. Consequently, the U.S. Fire Administration is initiating the first phase of a three-phase study of the impacts of different crew sizes on firefighting effectiveness and firefighter health and safety. As currently planned the study will involve (1) fireground simulations of different kinds of fires, with firefighter strain and fatigue being measured along with speed of suppression; (2) analyses of tasks performed by firefighters, given different crew sizes and different types of fires, and the ways in which task assignments produce or prevent opportunities for injury; (3) analyses of firefighter injuries and illnesses in actual fires along with other information on the speed of suppression and success in reducing property loss and preventing civilian casualties, with emphasis on identification of the relationship of all these measures to differences in crew sizes; and (4) mathematical modeling, statistical analysis, and computer simulations, as needed.

These different research approaches all need to be brought to bear on the problem, because they present different advantages and disadvantages. Task analyses and mathematical models are valuable because they can be sharply defined and their implications can be clearly identified. But these approaches have problems because they may omit important aspects of real situations. Fireground simulations and real fires, on the other hand, combine most or all of the elements of reality, but the effects of these elements may be difficult to separate, especially since it is difficult to assemble a sufficiently large number of fires or simulations for meaningful analysis. From these different research approaches, data could be obtained and synthesized to show the effects of crew size on the rates of firefighter and civilian deaths and injuries, and on the magnitude of property loss.

SUMMARY AND CONCLUSION

Over the past several decades, the industrial worker has received considerable attention with respect to occupational safety and health matters. The establishment and enforcement of safety and health standards has played a significant role in improvements in occupational safety. This is supported by U.S. Department of Labor statistics indicating a continuing reduction of injuries and deaths of industrial workers.

The improvement in industrial safety and health is contrasted by the increasing numbers of injuries and deaths of the Nation's firefighters.

The firefighter's clothing and equipment should allow him, or her, to perform the tasks required in the line of duty by providing a high degree of protection against the hazards which are expected to occur.

The importance of the information and recommendations contained in this report cannot be over-emphasized. If we are to expect firefighters to risk their lives to save us, our homes, and our businesses, we must improve our efforts in providing the best possible protective equipment and training that is possible.

FOOTNOTES

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CREDITS

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